



# **US LHC Accelerator Research Program**

***bnl - fnal- lbnl - slac***

## Design Studies: FY05 work status and FY06+ goals

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## Design Studies: mission and structure

The role of Design Studies in LARP magnet R&D:

- magnet CDS before modeling – proposal generation or evaluation including magnet parameters, design concept, cost, schedule ->prototype design
- theoretical CDS (we can not afford modeling everything in LARP) – magnet parameter space, radiation dose and life-time, exotic magnet designs (double-aperture dipole and quadrupoles with parallel and non-parallel apertures), etc. -> IR design

In FY2005 we identified three key directions for LARP Magnet Design Studies:

- IR Quadrupoles
- IR Dipoles
- IR Cryogenics

We are in a process of establishing working relationship with other LARP working groups including

- AP working group performing IR design studies
- Model magnet and Supporting R&D working groups



## Design Studies: FY2005 tasks

FY2005 acting tasks, task duration and task leaders are shown in Table

- we are working on forming task working groups
- practically all tasks are based on participation of at least 2 Labs
- work coordination is performed through the personal communications, video and phone conferences

WBS			
2	Magnet R&D		
2.1	Design Studies	A. Zlobin	
2.1.1	<i>Quadrupole</i>		
2.1.1.1	Shell & Block design comparison	P. Ferracin	FY05(Q3)
2.1.1.2	Shell mechanical design study	G. Ambrosio	FY05(Q4)
2.1.2	<i>Separation dipole</i>		
2.1.2.1	D1 design	R. Gupta	FY05-07
2.1.2.2	D1 cooling study	T. Peterson	FY05(Q4)
2.1.3	<i>Cryogenics</i>		
2.1.3.1	IR cryogenics study	R. Rabehl	FY05-06



## Design Studies: FY2005 budget

FY2005 DS budget and its distribution among 3 Labs is summarized in Table

- DS budget in FY2005 is <10% of the total LARP Magnet R&D budget
- due to limited budget in FY2005 the DS work at FNAL and LBNL is supported by Lab's funding

WBS		BNL	FNAL	LBNL	Total
2	Magnet R&D	214	400	491	1105
2.1	Design Studies	82	5	14	101
2.1.1	<i>Quadrupole</i>				
2.1.1.1	Shell & Block design comparison			5	5
2.1.1.2	Shell mechanical design study		5		5
2.1.2	<i>Separation dipole</i>				
2.1.2.1	D1 design	82		9	91
2.1.2.2	D1 cooling study				
2.1.3	<i>Cryogenics</i>				
2.1.3.1	IR cryogenics study				



## Task 2.1.1.1 status

**Task Name:** IRQ design comparison: shell-type vs. block-type

**Task leader:** P. Ferracin (LBNL)    **Participating laboratories:** FNAL, LBNL

**Task goals:** Investigate potential of racetrack quadrupoles for LHC luminosity upgrade. Continue the comparison of racetrack-type and shell-type IR quadrupoles started in FY2004.

**Milestones:**

- Development and coordination of magnet design parameters and criteria (Q1)
- Block-type and shell-type IRQ design analysis (Q2)
- Design comparison and conclusions (Q3)

**Current status:** This task is making good progress. The comparison strategy was developed including the beam envelope, magnetic, mechanical, thermal, radiation and quench protection requirements. Several IR quad designs were generated and compared with 90 mm shell-type quads including magnetic and mechanical parameters. Next steps

- Radiation energy deposition analysis and its effect on magnet operation margin and life-time (thermal analysis, radiation dose)
- Quench protection

The task needs to be extended to FY06+.



## Task 2.1.1.2 status

**Task Name:** Possibilities and limits of IR shell-type quad mechanical designs based on Al-shell and collars+SS-skin

**Task leader:** G. Ambrosio (FNAL)     **Participating laboratories:** FNAL, LBNL

**Task goals:** Evaluation advantages and limitations of the mechanical concepts for large aperture, high-gradient, shell-type quadrupoles: 1) SS-collars and SS-skin, 2) Al-shell and iron pads using bladder and keys, 3) SS-collars and Al-shell using bladder and keys.

### Milestones:

- Complete the FEM analysis of shell-type quad design with 110-mm aperture, field gradient of 230 T/m, exploring two concepts (Q1-Q2):
  - SS-collars and welded SS-skin
  - SS-collars and Al-shell using bladders and keys
- Collect and review (for a fair comparison) FEM studies of mechanical designs with Al-shell and iron pads using bladder and keys (Q3).
- Develop concept of fabrication and assembly for each design (Q4).

**Current status:** Mechanical analysis is in progress revealing potential mechanical problems in 4-layer 110-mm IR quads. The analysis needs to be extended to smaller aperture magnets including 90-mm TQ models.



## Task 2.1.2.1 status

**Task Name:** D1 Dipole Design (open midplane)

**Task leader:** R. Gupta (BNL)      **Participating laboratories:** BNL, FNAL, LBNL

**Task goal:** Develop a magnet design that satisfies the requirements for the dipole first optics of LHC IR luminosity upgrade:

- Design has an open midplane that allows most of the energy to be transmitted outside the coil region keeping heat deposition in SC coil below its quench limit
- Magnet design is such that it can accommodate large vertical forces
- Magnet has a field quality that meets the beam dynamics requirements

### **Milestones:**

- Develop conceptual design of smaller aperture dipole D1a (Q1)
- Complete the 2D magnetic, mechanical and energy deposition analysis (Q2)
- Develop conceptual design of new medium aperture (120 mm) dipole D1 (Q3)
- Complete first iteration of magnet design and energy deposition calculations and start 3D mechanical analysis (Q4)

**Current status:** The task progressing according the plan. Conceptual designs of an open mid-plane dipole and its simplified POP model have been developed; 2D magnetic and mechanical analysis has been performed. The work will be continued in FY06+.



## Task 2.1.2.2 status

**Task Name:** D1 dipole cooling study

**Task leader:** T. Peterson (FNAL)      **Participating laboratories:** FNAL, BNL

**Statement of work:** The conceptual D1 dipole is reported to have an estimated 100-200 W/m heat load in the magnet cold mass at helium temperatures (1.9 K or 4.5 K). The goals of an analytical study is to check the implications of such large heat loads on the internal passage sizes and magnet structure, and to check under what conditions, if at all, removing 1 KW or more from a 10 meter magnet is feasible.

**Milestones:**

- Assemble information regarding magnet design options and anticipated heat deposition, outline the approach to the problem, begin analysis (Q2)
- Iterate and refine the cooling analysis (Q3)
- Final version of analysis and write report (Q4)

**Current status:** The work on this task has recently been started. To perform the analysis the details of present D1 mechanical structure will be used. We need to reinforce the task working group and establish coordination with 2.1.2.1 task. The duration of this task may be extended.





## Task 2.1.3.1 status

**Task Name:** Conceptual design, parameters, and comparison of inner-triplet cryogenics at 1.9 K and 4.5 K.

**Task leader:** R. Rabehl (FNAL) **Participating laboratories:** FNAL, LBNL(FY2006)

**Statement of work:** As design studies of 2<sup>nd</sup> generation IR magnets are performed to investigate possibilities for an LHC luminosity upgrade, the cryogenics system must also be considered. Analytical studies will be conducted to investigate and compare 1.9 K and 4.5 K inner triplet cryogenic systems and coil temperatures for both single-bore and double-bore IR triplet designs.

### **Milestones:**

- Develop cryogenic system models and establish figures of merit; assemble information regarding magnet design options and anticipated heat deposition, outline the approach to the problem, begin analysis (Q2)
- Perform analyses of cryogenic system options, generate reports (Q3+)

**Current status:** The work on this task has been started. Figures of merit including  $\Delta T$  from coils to feed box, required He II inventory, cold mass packing factor and compatibility with current cryostat diameter and feed boxes have been discussed. This task will be continued in FY06+, the plan will be presented. We need to reinforce the group working on this task and coordinate work with CERN.



# Summary

Organization of DS work in LARP collaboration is in progress

- major directions have been identified
- working groups have been formed and started working
- a good progress is expected in FY2005 in spite of limited funding

In FY2006+ we will continue working in three major directions

Some task reorganization will be made to provide more flexibility to program needs and address important practical issues

## 1. IR Quads

- Design studies of IRQ based on shell-type coils
- Block-type quads for a "quad first" IR

## 2. IR Dipoles

- Open Midplane Separation Dipole
- Very large aperture dipoles for a "dipole first" IR

## 3. Cryogenics

- IR cryogenics and heat transfer studies